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VASCULAR PLANTS ON THE CINDER CONE OF PARICUTIN VOLCANO IN 1958

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The birth of Parícutin Volcano in a cornfield in the state of Michoacán, Mexico, in 1943 has provided an unparalleled opportunity for the study of volcanism and its effects. The eruption immediately attracted the attention of geologists, whereas biological phenomena were given relatively little consideration in the early years of the Volcano. Geological interest has subsided since the eruptive phase ended on March 4, 1952, but problems for the biologist are becoming increasingly evident. During the active period botanical studies were focused mostly at the destructive nature of the volcanic ejecta (Eggler, 1948, 1959) and the manner of preservation of a potential fossil record in the lava and ash (Dorf, 1945, 1951). The colonization by plants and animals of the wholly inorganic deposits of Parícutin now deserves a thorough, long-term scrutiny.

In the summer of 1958, while in Mexico for a study of the alpine flora in that country, I had the opportunity to make a side trip to Parícutin. The primary motive of this visit was to determine whether or not the same pioneer plant species might be involved in primary succession on volcanic deposits of a new volcano as are found in the alpine flora on the older and much larger volcanoes. In addition to age and size distinctions between Parícutin and the mountains with alpine vegetation, there is also a considerable difference in elevation. The cone of Parícutin has a maximum elevation of about 2800 meters, while the lower limit of the alpine flora is mostly above 3900 meters elevation. No species common

to the two areas were found, but the unexpected result of this visit was the discovery that 14 species of vascular plants already had gained a foothold on the cinder cone of Parícutin only six and a half years after volcanic activity had ceased.

For several reasons it appeared that the limited time available for this study could best be spent on the cinder cone. The lava flows, covering nearly 25 square kilometers (Fries and Gutiérrez, 1954), would be very difficult to examine critically in a short while, and much of the pyroclastic ejecta extend for hundreds of kilometers with no well-defined limits. The cone is the most prominent feature of the Volcano, and its age and history are thoroughly documented. It is small enough to allow observations that can be repeated from time to time by independent investigators. Although small, the cone provides a rather wide diversity of habitats. This report is thus concerned with the vascular plant species which are beginning to establish themselves on the cone of Parícutin.

GEOGRAPHY AND GEOLOGY

Parícutin Volcano is located in central western Michoacán approximately 30 kilometers WNW of Uruapan. Two former villages, Parícutin and San Juan Parangaricutiro, were buried by lava early in the life of the Volcano, and now the closest settlement is Angahuan about seven kilometers to the ENE. Parícutin lies in the zone of hundreds of volcanoes which crosses Mexico from east to west between the parallels of 18° and 22° N. latitude. It is situated about 10 kilometers north, on the lower slope, of the long extinct Cerros de Tancítaro which rises to an elevation of 3860 meters. In a report on the volcanoes of the Parícutin region, Williams (1950) indicated that more than 150 cinder cones and over 20 large lava cones were present in the area covered by his geological reconnaissance map (about 50 x 60 kilometers). In contrast to the massive Cerros de Tancítaro, most of the volcanoes in the region are about the same size as Parícutin. The most distinctive features of Parícutin are its youth and well-known geological history. The series of biological events now in action there must have previously taken place in a similar fashion on all of the other volcanoes.

From the original vent in the cornfield at an elevation of about 2400 meters, the cinder cone of Parícutin grew to a height of 10 to 12 meters in one day. In six days it was 167 meters high with a basal diameter of 730 meters and a crater diameter of 90 meters. Within 25 days the cone was about 200 meters high, and nine months after birth its present dimensions had nearly been attained (Foshag and Gonzáles R., 1956). Subsequent growth was much slower because of the large area over which ejected material was spread, and

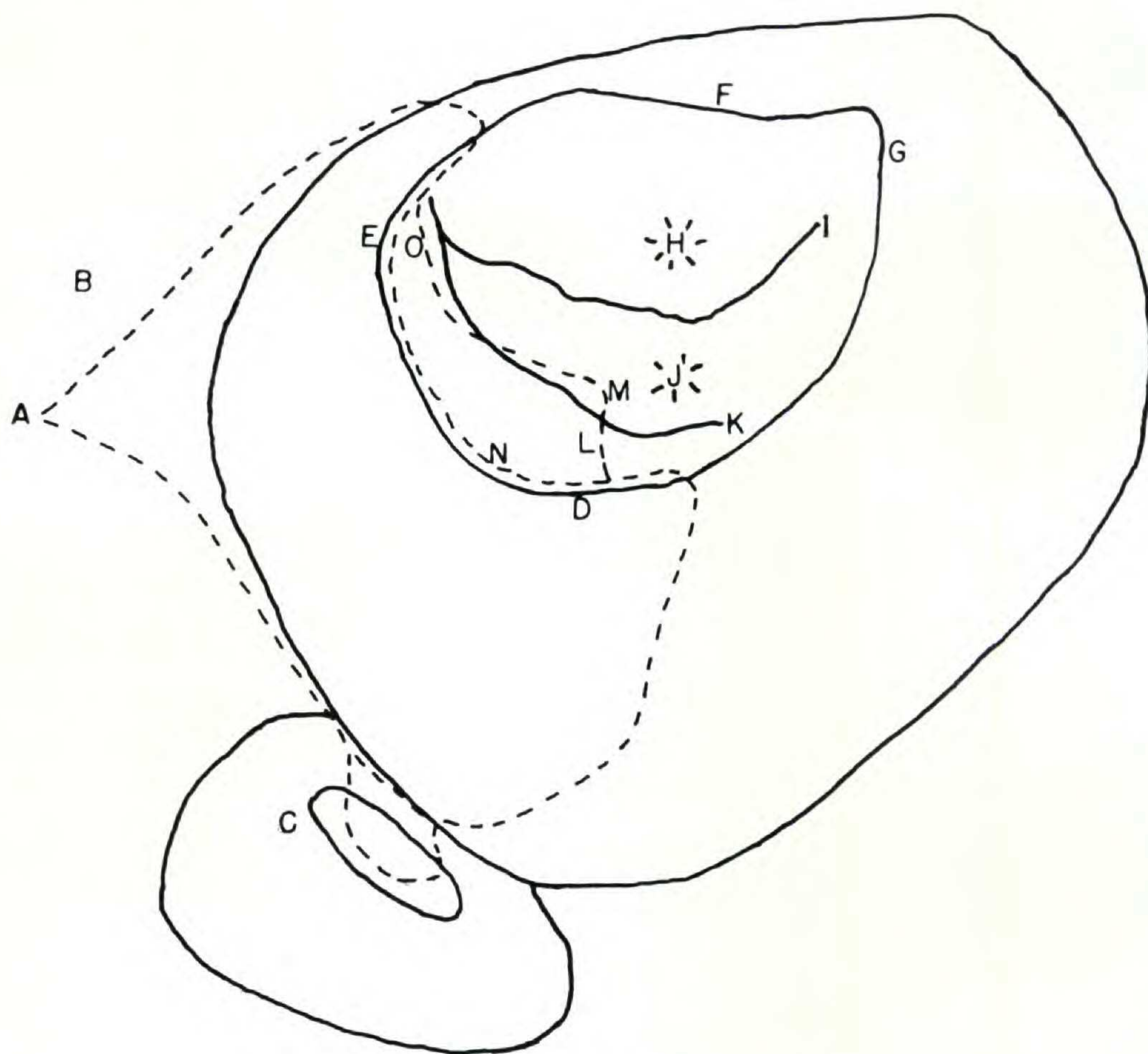


FIG. 1. Sketch of the cone of Parícutin Volcano looking southwesterly (modified from an oblique aerial photograph in Fries and Gutiérrez, 1954). A, route taken on cone; B, east base of cone; C, Nueva Juatita lava-vent mound; D, northeast saddle on rim of cone; E, east peak of rim; F, southwest saddle of rim; G, west peak of rim; H, southwest crater vent; I, ridge between crater vents; J, northeast crater vent; K, slump line; L, collection locality of *Pityrogramma calomelanos*, *P. tartarea*, *Pteridium aquilinum* var. *feei*, and undetermined fern; M, collection locality of *Pinus montezumae* ? ; N, collection locality of undetermined dicot seedling; O, collection locality of *Pellaea ternifolia* var. *ternifolia*, *Aegopogon cenchroides*, *Buddleia cordata*, *Aster exilis*, *Conyza coronopifolia*, *Eupatorium pazcuarensis* ? , *Gnaphalium attenuatum*, and *G. semiamplexicaule*.

the increment from later ejecta was about balanced by erosion and slumping. Although the nearly final size of the cone was developed in a very short time, the exact morphology was not stabilized until activity ceased (Fries and Gutiérrez, 1954). Slumping of the sides occurred several times as a result of the flowing out of lava beneath. After slumps the cone sides were rebuilt by the ejection of pyroclastic material from the crater vents.

The dimensions of the cone on May 1, 1952 (three months after activity ceased) from measurements made by Fries and Gutiérrez (1954) are as follows: West peak, 2808.6 m. elevation; east peak, 2807.9 m. elevation; lowest point on the northeast rim, 2770.3 m. elevation; peaks of crater rim about 410 meters above original level of cornfield; base of cone oval with northeast-southwest diameter of about 650 meters and northwest-southeast diameter of 900 meters; crater rim nearly round with diameter of about 280 meters; bottoms of the two crater vents, aligned on northeast-southwest axis, about 30 or 40 meters below levels of northeast and southwest saddles on rim. The actual projection of the cone above its base is considerably greater than its apparent elevations because the lava flows immediately surrounding the cone are exceedingly thick. The Nueva Juatita lava-vent mound on the northeast side of the cone is only 79 meters below the lowest point on the rim of the crater. Although slumping, settling, and erosion have occurred since the 1952 measurements, the present dimensions of the cone probably are still very nearly equivalent. While the Volcano was still active the inclination of the outer slope of the cone ranged between 31° and 33° (Segerstrom, 1950).

Most of the cone is made up of successive layers of pyroclastic materials such as ash, cinders, lapillae, and bombs. Much of the upper crater surface is comprised of coarse to fine lapillae. The rim is mostly of fine cinders and ash with some larger fragments. The outer slope is of rather coarse rubble mixed with finer fragments. Segerstrom (1950) suggested that the base may contain some massive lava which does not extend very far up in the cone. According to Wilcox (1954) the petrographic character of the ejecta changed during the nine-year eruptive period from an olivine-bearing

basaltic andesite containing 55 percent silica to an orthopyroxene-bearing andesite containing over 60 percent silica. Williams (1950) indicated that the pyroclastic ejecta were identical with the lavas or differed only in having a higher glass content or a greater degree of vesicularity. At the end of activity in 1952, white crusts of ammonium chloride, deposited by exuding vapors, were conspicuous on the crater sides (Fries and Gutiérrez, 1954). Some of this material was still evident at the time of my visit in 1958, and gases were still being emitted by numerous fumarolic vents on both the cone and surrounding lava flows.

CLIMATE

The climate at Parícutin is temperate with a relatively cool, wet season from June to October and a cool, dry season from November to May. There are no climatic records for the area before the appearance of the Volcano, and the data are still inadequate. From rainfall records kept at two stations during most of the active period (cf. Fries and Gutiérrez, 1954) it can be seen that the annual precipitation varied from about 1300 to 2400 mm. Frosts and freezing temperatures occur during the winter months, but winter temperatures were reputedly milder during the eruptive period (Segerstrom, 1950).

PLANTS PREVIOUSLY REPORTED ON THE CONE

The first report of plants invading the cinder cone of Parícutin is by Eggler (1959) who indicated that in February of 1957 Mr. Kenneth Segerstrom of the U. S. Geological Survey found lichens and two species of angiosperms, probably a *Gnaphalium* and an *Eryngium*, growing on the rim of the crater. The *Gnaphalium* found by Segerstrom is very likely one of the two species of that genus obtained in the present study. Although no *Eryngium* was seen on the cone in this investigation, a specimen of *Eryngium beechyanum* (Beaman 2399) in full flower was found in volcanic ash at the edge of a deep gully about two kilometers east of the cone.

SPECIES FOUND IN 1958

The 14 vascular species found on the cone of Parícutin on September 1, 1958 are arranged by families below. Notes on habitats and certain other features of the plants are included. The route taken on the cone and the approximate

location of plants collected are shown in fig. 1. Voucher specimens are filed in the Herbarium of Michigan State University¹.

POLYPODIACEAE.

Pellaea ternifolia (Cav.) Link var. **ternifolia**. (*Beaman 2409*). Only two small plants, growing in volcanic ash kept moist by gases from a fumerolic vent, were found near the summit of the east rim of the crater. The smaller of the two specimens has numerous sporangia on the pinnae of some fronds.

Pityrogramma calomelanos (L.) Link. (*Beaman 2408C*). In the field this species was not distinguished from *P. tartarea*, and the two were inadvertently mixed in the collection. Either one or both species are common on the northeastern side of the crater among moderately coarse lapillae. These specimens are without sporangia.

Pityrogramma tartarea (Cav.) Maxon. (*Beaman 2408A*). See discussion under *P. calomelanos*. One plant of this collection, with a single frond, has young sporangia. Other specimens in the collection are sterile. A specimen of the same species obtained from the lava at the east base of the cone was much larger and had several well-developed fertile fronds. Both Eggler (1959) and Clausen (1959) have noted that this is a pioneer species on Parícutin lava flows.

Pteridium aquilinum (L.) Kuhn var. **feeii** (Fee) Maxon. (*Beaman 2408B*). This species occurs with *Pityrogramma calomelanos* and *P. tartarea* on the sides of the crater. Two juvenile, sterile specimens were collected. Eggler (1948, 1959) and Clausen (1959) have noted that this is a common species in the Parícutin area.

Undetermined juvenile fern. (*Beaman 2408D*). The single sterile plant obtained, growing with *Pityrogramma calomelanos*, *P. tartarea*, and *Pteridium aquilinum* var. *feeii*, is too immature to permit more than a guess as to its identity.

PINACEAE.

Pinus montezumae Lamb. ? (*Beaman 2410*). This seedling pine was growing about 10 meters below the northeast saddle

¹I am indebted to Dr. Rolla Tryon for determinations of the ferns and to Dr. Rogers McVaugh for recognizing the sterile specimens of *Aster exilis*, and for suggestions that lead to the determination of another species. My able native guide for the trip to the cone was Sr. José Cruz Gomez of Angahuan, Michoacán. A grant from the Penrose Fund of the American Philosophical Society made possible the field study in Mexico.

on the side of the crater. Only a single specimen was found. The substrate was of rather coarse lapillae, and no fumerolic vents were noted in the near vicinity. *Pinus montezumae* is one of the most important forest components around Parícutin, and this plant is very similar to a mature specimen (*Beaman 2412*) collected near by. The only other common species of pine observed in the area is *P. leiophylla* (*Beaman 2422*), and the seedling is definitely not that species. At least three other species (*P. pseudostrobus*, *P. michoacana*, and *P. teocote*, cf. Martinez, 1948) probably occur in the Parícutin region, but the seedling is more like *P. montezumae* than any of these. The specimen has secondary fascicles with only three and four needles (the species is typically five-needled), but variations above and below the usual number were found in other seedlings in the area. The plant was in at least its second season as indicated by the presence of both old, solitary primary leaves and younger secondary leaves.

GRAMINEAE.

Aegopogon cenchroides H. & B. (*Beaman 2411*). Two small plants of this species, one with a slightly developed inflorescence, were found in volcanic ash kept moist by gases from a fumerolic vent near the summit of the east rim of the crater. A much more vigorous plant of the species (*Beaman 2390*), already with several well-developed stolons, was found among lava boulders at the east base of the cone. This species was not observed in ash deposits that were examined several kilometers away from the cone, but the superficially similar species, *Cynodon dactylon*, was found to be an important pioneer in the ash.

LOGANIACEAE.

Buddleia cordata HBK. (*Beaman 2406*). A single seedling plant was obtained near the summit of the east rim of the crater in volcanic ash kept moist by gases from a fumerolic vent. Several larger plants of the same species (*Beaman 2396*) were scattered on the lava at the east base of the cone. *Buddleia cordata* is a common species in the Mexican volcanic highlands.

COMPOSITAE.

Aster exilis Ell. (*Beaman 2405*). This was the most abundant species in the moist volcanic ash by a fumerolic vent

near the summit of the east rim of the crater. None of the specimens had begun to flower, but other herbarium specimens of this common *Aster* closely match this collection.

***Conyza coronopifolia* HBK.** (*Beaman 2407*). Three small plants, two in flower, were found in the same area with *Aster exilis*. *Conyza coronopifolia* is a common weedy species in the Mexican volcanic highlands.

***Eupatorium pazcuarens* HBK. ?** (*Beaman 2403*). Five sterile plants of this species were found near the summit of the east rim of the crater in moist volcanic ash near a fumerolic vent. Several species of *Eupatorium* in this complex are very similar vegetatively, thus making determination difficult. A few larger plants (*Beaman 2393*) with dried flowering stems of the previous season still attached were found on moist lava cliffs at the east base of the cone. These closely resemble other herbarium specimens of *E. pazcuarens* from Michoacán.

***Gnaphalium attenuatum* DC.** (*Beaman 2404*). Four plants, one beginning to flower, were collected in the vicinity of a fumerolic vent near the eastern summit of the rim of the crater. Two specimens with abundant inflorescences (*Beaman 2394*) were found on lava at the east base of the cone.

***Gnaphalium semiamplexicaule* DC.** (*Beaman 2412*). Two specimens, one a rosette and the other at a slightly older stage, were obtained from the area near the summit of the east rim of the crater. Four other specimens (*Beaman 2392*) in bud and flower, were found on lava at the east base of the cone.

FAMILY UNDETERMINED.

Undetermined dicot seedling. (*Beaman 2402*). This single plant was growing on the saddle of the northeast rim of the crater. No other plants were observed in the immediate area, but the pine seedling and the ferns (except *Pellaea ternifolia* var. *ternifolia*) were collected on the side of the crater not far below this point on the rim.

DISCUSSION

An extensive survey of the flora of the Parícutin region has not been published, but a floristic study of the south side

of the neighboring Cerros de Tancítaro was made by Leavenworth (1946). At comparable elevations many species are common to these two areas, but only six of the 14 species found on the cone of Parícutin were also collected by Leavenworth. Observations on the vegetation in the vicinity of Parícutin were made by Eggler (1948, 1959) and Clausen (1959), but their interests were not primarily floristic. Only two of the species (*Pityrogramma tartarea* and *Pteridium aquilinum*) which Eggler (1959) noted for their ability to survive or reproduce in the volcanically affected soils were found on the cone in this study. I made some effort to locate in near by areas the same species that were collected on the cinder cone. This attempt was most successful on the lava flows adjacent to the cone where six of the same species were found. A thorough study of the flora of the Parícutin region is still needed to give some measure of the overall importance of species as they colonize the barren volcanic deposits.

It seems highly probable that all of the species on the cone were carried there as wind-borne propagules, although dispersal by animals, especially birds, cannot be entirely discounted. The Polypodiaceae and the Compositae, both with five species, are predominant in the cone flora, while the other three determined species belong to different families. The small size of the fern spores makes them well adapted to wind transport. All of the Compositae found on the cone are species with a well-developed pappus. The winged seeds of the pine make wind dispersal also the likely method of its transport. *Aegopogon cenchroides* has small, light spikelets with several awns which would serve in wind dispersal about as effectively as the pappus of the composites. The *Buddleia* species has very small seeds which could be blown by wind for a considerable distance.

Soil conditions, in contrast to those in which the species ordinarily occur, must be extremely inorganic on the cone. Organic products would be present only through the biological actions of the earliest pioneer species or by being transported there from surrounding areas. These sources must have already contributed some organic materials, but the

cone substrates probably have not yet been significantly altered. In the studies of Katmai Volcano in Alaska, Griggs (1919) noted that a scarcity of organic nitrogen retarded revegetation more than any other factor. Eggler (1959) suggested that ammonium chloride deposits, which are abundant on the cone of Parícutin, may provide a nitrogen source for plants.

Substrates on the cone in which plants were growing can be roughly classified into three types: Moist ash near fumarolic vents, relatively coarse lapillae on the crater sides, and ash on the crater rim away from fumarolic vents. Eight species were found by the fumarolic vents, five in the lapillae on the side of the crater, and only one, a small seedling, in ash away from fumarolic vents on the rim of the crater. No plants were found on the outer slopes of the cone, possibly because the rubble is coarser and less stable, and there is a lack of fumarolic vents. The concentrations of plants in wet habitats on both the cinder cone and on surrounding lava flows suggest that water is an especially important factor in enabling species to become established. A thorough assessment is needed of the role of non-vascular species in modifying habitats on the volcanic materials.

The success in establishment of species on the cone should be reflected, to a certain extent, in their maturity and vigor. A rather long period would have been necessary for the two woody species, *Pinus montezumae* ? and *Buddleia cordata*, to attain a reproductive age. Three herbaceous angiosperm species, *Aegopogon cenchroides*, *Conyza coronopifolia*, and *Gnaphalium attenuatum*, had flowered; and two ferns, *Pellaea ternifolia* var. *ternifolia* and *Pityrogramma tartarea*, had produced sporangia. The other species were still only in a vegetative state. All of the fern species had a distinctly juvenile appearance. Although none of the plants were especially robust, the fact that five species had reached reproductive maturity is noteworthy.

Most of the species observed on the lava at the eastern base of the cone were more vigorous than those on the cone, yet that lava could hardly have been colonized by plants any earlier than the cone itself. Part of this area received one of the last flows to be emitted from the Volcano in 1952

(Fries and Gutiérrez, 1954). *Eupatorium pazcuarense* ? on the lava had flowered in the previous season, and both species of *Gnaphalium* and the *Buddleia* were exhibiting vigorous growth. Several healthy specimens of *Calamagrostis pringlei* (Beaman 2389, not present on the cone) were also well established. In the lava there are numerous basins, protected crevices, and caves to collect ash, silt, and water which produce conditions favorable for plant growth. Likewise, greater protection against extremes of evaporation and erosion is afforded by the lava. Clausen (1959) reported finding eight species of ferns, two mosses, and two *Gnaphaliums* on lava (deposited 11 years before his visit) near San Juan Parangaricutiro. Egglar (1959) indicated that in 1950 he found a blue-green alga and mosses growing on flows after three years, and after four years three species of ferns were established.

The brief period between the cessation of activity by the Volcano and the discovery of plants on its cinder cone demonstrates that only a short time is necessary for the initiation of primary succession. Parícutin now provides a model design for the study of plant dispersal, establishment, succession, and community development on inorganic volcanic products. — DEPARTMENT OF BOTANY AND PLANT PATHOLOGY, MICHIGAN STATE UNIVERSITY, EAST LANSING.

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CONTRIBUTION TO THE FUNGUS FLORA OF NORTHEASTERN NORTH AMERICA¹

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In the following account, seven species of agarics are discussed by the senior author. *Hygrophorus purpureofolius* is described as a new species, and the new combinations *Clitocybe hudsonianus* (Jenn.) Bigelow and *Lyophyllum multiforme* (Pk.) Bigelow are proposed. Information on the three pyrenomycetes has been prepared by the junior author, and the new combinations *Anisostomula rubescens* (Ell. & Everh.) Barr and *Gnomonia acerophila* (Dearn. & House) Barr are proposed.

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Colors cited in the descriptions of agarics, except in the case of *Clitocybe hudsonianus*, are from Ridgway, R. 1912. *Color standards and color nomenclature*, Washington, D. C. The colors given for *Clitocybe hudsonianus* are from Villalobos-Dominguez, C. and J. Villalobos. 1947. *Atlas De Los Colores*, Buenos Aires.

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